Memorandum

To: Marguerite Carpenter, FMC Corporation **Date:** December 15, 2015

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Subject: FMC Pocatello, Idaho – Evaluation of Off-Site Disposal of USC Material and Sand

Executive Summary

FMC produced elemental phosphorous at its phosphate ore processing facility in Pocatello, Idaho from the late 1940s to 2001. The site-wide grading that has been conducted as part of the ongoing remedial action at the facility under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) has encountered phosphorus-containing materials, primarily at the facility's slag pile, that were not previously documented as to location. The CERCLA site documentation refers to these as Undocumented Subsurface Conditions (USC) materials. The presence of phosphorus in the USC materials creates potential hazards to the site workers who handle it due to the fact that phosphorus can burn when exposed to air and create irritant phosphorus pentoxide smoke, and can generate toxic phosphine gas if in contact with water (FMC 2015; US EPA Region X, 1998). This memorandum compares the risks to human health and the environment for an on-site disposal option and an off-site disposal option, with the options defined as follows:

- Option 1: On-site consolidation and capping.
- Option 2: Drumming materials from both the former coke basin and RA-F2; transport and disposal at an incineration facility in East Liverpool, Ohio.

Off-site disposal involves drumming and transport of USC materials in 55-gallon drums, which were assumed to hold 500 lb/drum. Drumming of the material from both on-site locations[1] is expected to produce 4,231 drums. There are significantly increased risks to on-site workers, off-site truck drivers, and the general population with off-site disposal of the USC materials, as compared to the on-site disposal option.

- The on-site risks resulting from the physical labor required to implement Option 2 (load drums by hand and prepare drums for transport) *vs.* Option 1 (consolidate and cap) are higher by a factor of 52 for both risk of injury and risk of fatality.
- The total risk of fatality for workers is almost 500 times more for workers in Option 2 than Option 1.
- The total risk for worker injury is nearly 100 times greater in Option 2 than in Option 1.

[1] The USC materials contain phosphorus-contaminated debris and sand. The number of drums required is based on an assumption that only 33% of the sand will be entrained with the USC materials and included in what is placed into drums.

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- Based on the truck route between Pocatello, Idaho and East Liverpool, Ohio, it is estimated that 14% of the truck miles traveled would occur in urban or urban cluster areas. If an estimated 1% of truck crashes that result in property damage also result in release of phosphine gas, then the risk of a chemical release in a populated area is 3.05×10^{-4}.[2]
- Option 2 has a total estimate of 0.1[3] persons injured or killed during transport due to truck crashes, based on a total travel distance of approximately 242,000 truck-miles (Table 2).
- Transport is also associated with greenhouse gas emissions (negligible under Option 1). Under Option 2, emissions would include over 35,000 lbs of CO_2 and over 120 lbs of PM_{10}.
- In addition to the risk quantified above, risks would be increased for workers under Option 2 because there is unknown amount of larger objects among the USC materials that may require mechanical crushing *via* a skid steer mounted hydraulic hammer or other type of crusher to fit into 55-gallon drums.

Worker Injury and Fatality Rates

- Background – Consideration of risks to workers during remediation is central to evaluating the short-term effectiveness Balancing Criteria under CERCLA and the National Contingency Plan (NCP):
  - The NCP requires consideration of "[p]otential impacts on workers during remedial action and the effectiveness and reliability of protective measures" during the evaluation of short-term effectiveness (300.430(e)(9)(iii)(E));
  - CERCLA states that "the potential threat to human health and the environment associated with excavation, transportation, and re-disposal, or containment" must be evaluated during remedy selection (9621(b)(1)(G));
  - US EPA's (1988) Remedial Investigation/Feasibility Study (RI/FS) Guidance states that "threats that may be posed to workers and the effectiveness and reliability of protective measures that would be taken" (p. 6-9) should be considered;
  - US EPA's (1991) Risk Assessment Guidance for Superfund (RAGS) Part C states risks that occur during remedy implementation may be considered during the remedy selection phase, including the "potential for injury due to physical hazards" (p. 20).
- Site-specific analysis:
  - At the FMC Site, Option 2 (Drumming and Off-site Transport) involves significantly more worker labor, including construction laborers and truck drivers, than Option 1. The drumming portion of Option 2 involves significantly more contact with the USC material than Option 1. As a consequence of this contact, the risks of worker injury due to exposure to phosphorus contaminated material is increased. As a consequence, the occupational risks of worker fatalities and injuries associated with Option 2 are much higher than Option 1, as summarized in Table 1. For Option 2, occupational injury and fatality risks increase by almost 100 and 500 times, respectively, over Option 1.
  - During the design of process safety controls, FMC targets a low fatality risk of 1×10^{-6} (1 in 1,000,000). While the risks of fatality under Option 1 (8×10^{-6}) slightly exceed the FMC

[2] Calculated as round-trip miles (242,269 miles) x Property damage accidents (89.9 per 100 million miles driven) x roads in urban populated areas (14%) x estimated percent of truck crashes (1%).
[3] 0.094 injuries in large truck crashes + 0.0035 fatalities in large truck crashes = 0.098 total injuries and fatalities.

safety target, the risks of fatality for on-site workers under Option 2 (4.1×10^{-4}) significantly exceeds the FMC worker safety target.

Table 1 Occupational Injury and Fatality Rates

Risk Category	Option 1: On-site Disposal	Option 2: Drumming All Materials	Option 2: Transport All Materials	Factor higher for Option 2 *vs.* Option 1
Weighted Average Injury Rate (per 10,000 hours)	1.4E-01[a]	2.5E-01[a]	2.3E-01[b]	-
Weighted Average Fatality Rate (per 10,000 hours)	5.5E-04[a]	9.8E-04[a]	8.8E-03[b]	-
Labor (Equivalent Worker Hours)	144	4,200	4,033	-
Risk (μ)[c] of injury (number of injury incidents)	2.0E-03[a]	1.0E-01[a]	9.4E-02[b]	Option 2: 99x
Risk (μ)[c] of fatality (number of injury incidents)	8.0E-06[a]	4.1E-04[a]	3.5E-03[b]	Option 2: 495x
Probability of at least one fatality (P)[d]	8.0E-06[a]	4.1E-04[a]	3.5E-03[b]	-

Notes:
(a) Rate of incidents for on-site workers only (US Dept. of Labor, 2009, 2011). Incidents include fatal and non-fatal injuries or illnesses of construction workers in private industry due to slips, trips, falls, contact with objects, overexertion, transportation accidents, exposure to harmful substances or environment, fires, explosions, violence, injuries by persons or animals.
(b) Rate of incidents for truck drivers and general public in a crash involving large trucks (US DOT, 2014).
(c) Risk (μ) = equivalent worker hours x weighted average rate.
(d) (P) is estimated using a Poisson distribution, where $P = 1 - e^{-\mu}$.

In addition to injuries and fatalities due to accidental exposure to phosphorus-contaminated material, the likelihood of heat-related illnesses occurring in workers is increased when workers use personal protection equipment (PPE). The BLS reports that 0.3% of nonfatal occupational injuries are related to heat or light (US Dept. of Labor, 2013). During drumming, workers are protected from accidental exposure to phosphorus-contaminated material through the use of aluminized suits, face masks, and gauntlet gloves. High temperature, high humidity, and direct sun exposure are the most important risk factors for heat-related illnesses. OSHA recommends that precautions, including work/rest schedules, are implemented when the heat index is 91°F or greater (OSHA, 2015). Rates of heat-related illnesses are also influenced by a number of other factors including climate, strenuousness of labor, work/rest cycles, medical conditions, fluid intake, physical fitness, and age.

Potential Exposure to Human Populations

- An analysis of the potential route for trucks carrying hazardous substances using US DOT National Highway Network data and US DOT Hazardous Material Routes indicates the one-way distance from the site to the incineration facility is 1,954 miles (US DOT, 2015a,b; ESRI, 2015). The round trip distance for each truck is 3,908 miles.
- The potential route from Pocatello, Idaho to East Liverpool, Ohio crosses 16 urbanized areas which include populations of 50,000 or more people and an additional 19 urban cluster areas which include populations of 2,500 to 50,000 people (US Census Bureau, 2015). Approximately 14% of the route traverses these urban areas.[4]
- The transport of drummed materials is expected to involve a total round-trip distance[5] of 242,000 miles for Option 2 using US DOT Hazardous Material Routes. Data indicate the risk of injury or fatality to non-workers and workers is 0.0000004 per mile. Thus the total estimate for persons injured or killed during transport is 0.098 for Option 2 (Table 2).

Table 2 Injuries and Fatalities Rates for Large Trucks

Risk Category	Risk Estimate	Option 2 Estimates of Risk for All Materials
Injuries in Large Truck Crashes (persons per mile)	3.90E-07	0.094
Fatalities in Large Truck Crashes (persons per mile)	1.50E-08	0.0035
Total Injuries and Fatalities:		0.098

Notes:
The risks are calculated as Risk Estimate x Distance x Trips. Option 2 assumes 62 truck trips to transport 4,231 drums.
The injury and fatality estimates developed here based on miles traveled are essentially the same as those presented in the table above that are based on hours driving.

- Truck crashes that do not involve injury or fatality (*e.g.*, property damage only), occurred in 2012 at a rate of 89.9 accidents per 100 million miles driven (US DOT, 2014). Based on the total round-trip distance expected, the risk of a truck crash involving property damage alone under Option 2 is 0.22. Some percentage of such accidents may result in a release of phosphine gas, with potential exposure of the surrounding population. If we assume for illustrative purposes that 1% of such crashes will result in a release of phosphorus contaminated materials, and take into account that 14% of the miles driven are in urban or urban cluster areas, this yields the risk of a chemical release in an urban area of 3.0×10^{-4} for Option 2.

[4] The one-way distance 1,953 miles includes 275 miles (14%) of roads in urban areas or clusters.
[5] Option 2 assumes 62 truck trips traveling 3,908 round-trip miles for a total of 242,269 miles.

Greenhouse Gas Generation

- While onsite air emissions associated with Option 2 are expected to be minimal, our calculations indicate that greenhouse gas emissions associated with transporting 4,231 drums from Pocatello, Idaho to East Liverpool, Ohio using the hazardous substance-specific routes would be significant. For Option 2, greenhouse gases may be produced during transport as detailed in Table 3.
- Option 2 mileage (242,269 round-trip miles) results in the release of approximately 120 pounds each of respirable particulates of either size fraction 2.5 micrometers or 10 micrometers, 240 pounds each of volatile organic compound emissions or total hydrocarbon emissions, 1,200 pounds of carbon monoxide, nearly 5,000 pounds of nitrogen oxides, and 35,000 pounds of carbon dioxide (Table 3).
- Additional greenhouse gas emissions associated with incinerating the contaminated material are not included in the emissions estimates, but could also be estimated.

Table 3 Greenhouse Gas Emissions Rates

Pollutant	**Option 2 (Transport of total materials in 4,231 drums)** ***Pounds***
VOC	243
THC	246
CO	1,279
NOx	4,909
$PM_{2.5}$	115
PM_{10}	124
CO_2	35,251

Note:
The estimates for CO_2 were calculated based on 2017 US EPA Emissions standards for low roof, sleeper cab tractors (US EPA, 2011). All other pollutant estimates were calculated based on Average In-Use Emissions for heavy-duty, diesel, long-haul semi-tractor trailer rigs (US EPA, 2008).

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